The Effect of Isopycnal Mixing in HadCM3

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What is Isopycnal Diffusion?

- A parameterisation of sub-grid-scale stirring, which occurs along surfaces of constant density.
- It can transfer heat vertically as well as horizontally, because the salinity also effects the density of sea water (see figure 1).
- HadCM3 uses a constant value for the diffusivity, however this is not true of the real ocean, so there is parameter uncertainty. Experts have judged the diffusivity to fall within the range 2000m^2s^{-1} to 200m^2s^{-1}.
- This work looks at what effect this uncertainty may have on climate and climate change.

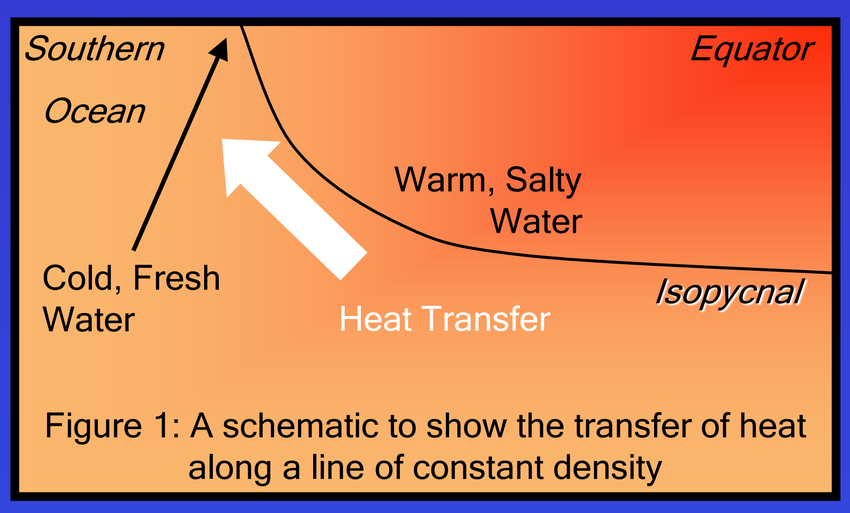

Figure 1: A schematic to show the transfer of heat along a line of constant density

The Integrations Performed

- Three runs performed as part of a perturbed physics ensemble.
- 500 year spin up from Levitus observations followed by 80 year control and 80 year global warming (1% per year increase in CO_2)
  1. *High Isopycnal Diffusivity - (2000 m^2s^{-1})*
  2. *Standard HadCM3 - (1000 m^2s^{-1})*
  3. *Low Isopycnal Diffusivity - (200 m^2s^{-1})*

Differences in the Control Climate

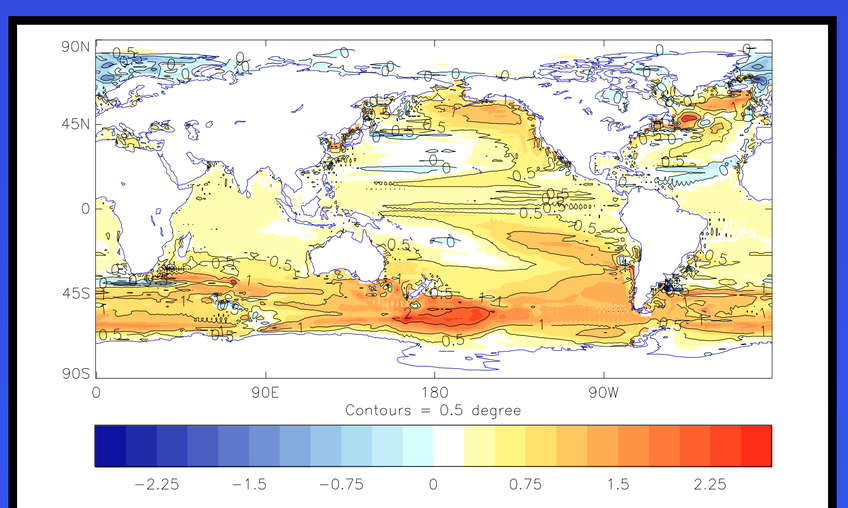

Figure 2: Sea Surface Temperature differences due to isopycnal diffusion in the control climate. The average SST of the high diffusion control run minus the average of low diffusion control run.

Increasing the isopycnal diffusion should transfer more heat to the surface in the high latitudes (see fig. 1). This is confirmed by the differences of over 1°C in the Southern Ocean between the high and low diffusivity control climates (shown as fig. 2). This surface heat comes from the intermediate waters, forming a subsurface cool anomaly (fig. 3). The tropical SST anomaly is likely due to heat being transported around the gyre.

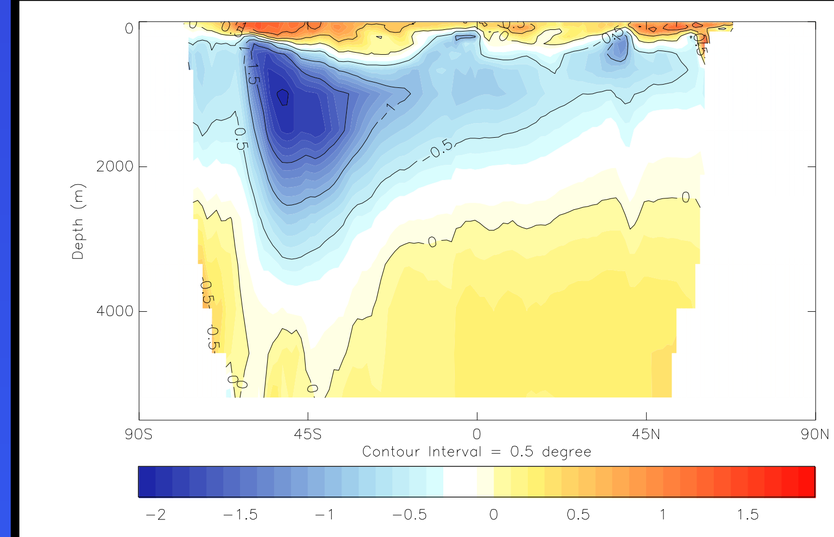

Figure 3: A zonally averaged cross-section of the Pacific, showing the potential temperature difference between the high diffusivity and the low diffusivity run.

Differences in the Global Warming Signal

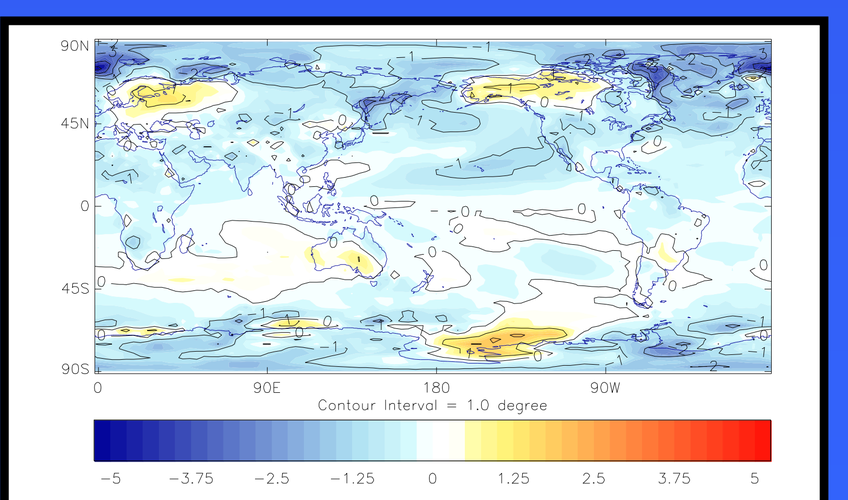

Figure 4: Surface air temperature differences in due to isopycnal diffusivity change from max to min in the decade of doubled CO2 with the control climate removed to avoid climate drift.

The global warming signal is the average of years 70-80 in the increasing CO2 run minus the average of years 70-80 in the control run. The difference between the signals of the high and low diffusivities is less than 1°C over the majority of the globe (fig 4). Even small differences represent significant uncertainty in the global warming signal (Fig. 5). The differences at high latitudes are due to the different sea-ice in the control climates.

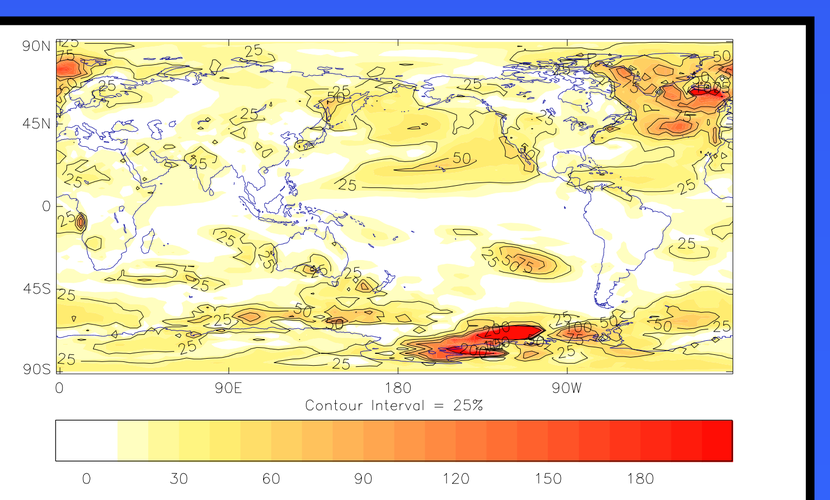

Figure 5: The surface air temperature differences of figure 4, shown as a percentage of the standard model's global warming signal (the average of years 70-80 in the increasing CO2 run minus the average of years 70-80 in the control run)

Conclusions

- Isopycnal mixing is important in the heat balance of the ocean at high latitudes
- Uncertainty in the isopycnal diffusivity causes uncertainty of up to 2°C in the temperature of the ocean.
- Aside from the effects of differing sea-ice simulations, uncertainty in the isopycnal diffusivity causes uncertainty of up to 50% in the global warming signal.